HAILSTORMS IN WISCONSIN

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ABSTRACT

A climatological study of hailstorms is presented for the State of Wisconsin and for four first order weather stations: Green Bay, La Crosse, Madison, and Milwaukee. The analysis considers the geographical and time distribution of hail and the ratio of monthly average number of hailstorms to monthly average number of thunderstorms.

1. INTRODUCTION

Formidable among the weather and climatic hazards to property and crops of the interior plains of the United States is the hailstorm, which is to be ranked with drought, the tornado, and the windstorm. The annual hail loss in Wisconsin has varied from a few thousands to millions of dollars [1]. Investigation of hail damage in Wisconsin by the authors for the year 1962 indicates that the figure for crops and property damage may be close to $2 million, which is exceptionally large for Wisconsin.

A climatological analysis of hailstorms in Wisconsin, with emphasis on geographical and time distribution, and a consideration of the ratio of the monthly average number of hail storms to the monthly average number of thunderstorms is presented.

No comprehensive analysis of this type had been made previously for the State. The authors recognize many studies of hailstorm distribution in the United States which have included Wisconsin, by Flora [2], Visher [3], Lemons [4], and U.S. Weather Bureau [5], [6]. These previous studies present only a general description of Wisconsin hailstorms.

Noteworthy have been several climatological studies of hailstorms in Illinois by Changnon [7], [8], [9], [10]. The latter study reported on the areal frequencies of hail and thunderstorms for Illinois. Other related studies showing geographical distribution of hail, frequency of hail, and damage by hail were completed by Huff and Changnon [11], Roth [12], and Stout et al. [13].

2. DATA

Hail in this study is defined as precipitation in the form of balls or irregular lumps of ice, always produced by convective clouds, nearly always cumulonimbus. It does not include soft hail or graupel.

Severe hail is defined, in accordance with usage in the Weather Bureau's *Storm Data*, as cases in which at least one of the following criteria was fulfilled: (a) hailstones $\frac{3}{4}$ in. or more in diameter, (b) unusual for the season, (c) one or more deaths or injuries by hail, (d) property or crop damage in excess of $10,000 by hail.

Data were taken from the official records of first-order and cooperative Weather Bureau stations in Wisconsin. Cooperative weather stations are spaced fairly uniformly over the State, with first-order stations located at Green Bay, La Crosse, Madison, and Milwaukee. There has been a general increase in the number of cooperative stations; however, the number has decreased during some periods. For example, the number of stations in 1914 was 95, decreasing to 86 in 1924, and increasing to 213 in 1962.

This report places special emphasis on records of hailstorms and thunderstorms at first-order Weather Bureau stations where these records are more complete. Examination of the cooperative weather station records indicates a tendency of the observer not to report all storms, particularly when the hail is light or thunder is distant. This is partially explained by the fact that the cooperative observer may be away from his place of observation at the time of hail occurrence, or the storms occur during sleeping hours. For these reasons, the statewide analysis can be considered as biased on the low side but indicates general tendencies or trends.

The observational instructions for the recording of hail and thunderstorms should be considered. A thunderstorm is to be reported whenever thunder is heard, regardless of how faint. Under favorable conditions, thun-

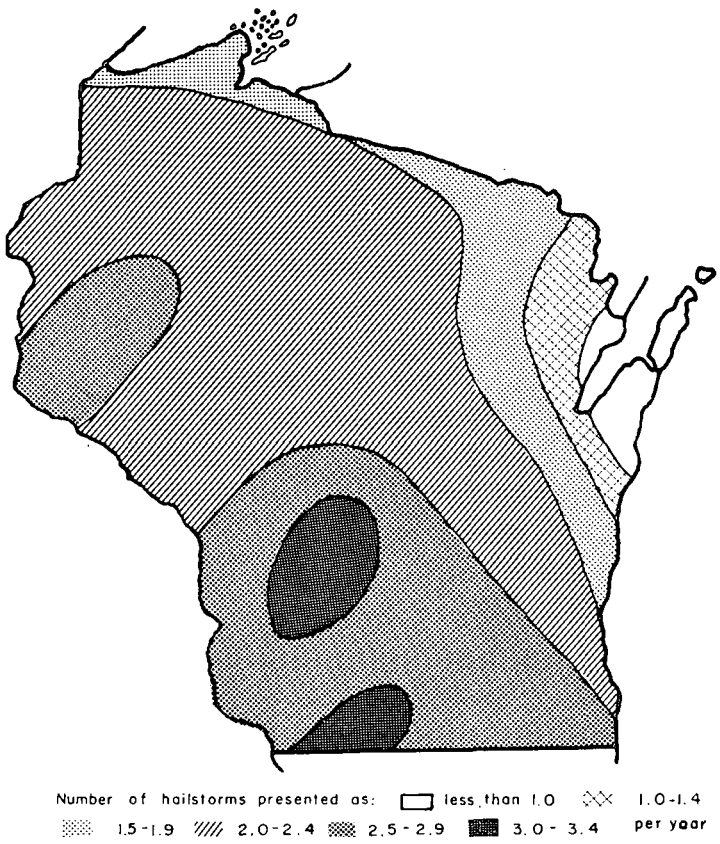

FIGURE 1.—Geographical distribution per year of hailstorms in Wisconsin, 1948–57.

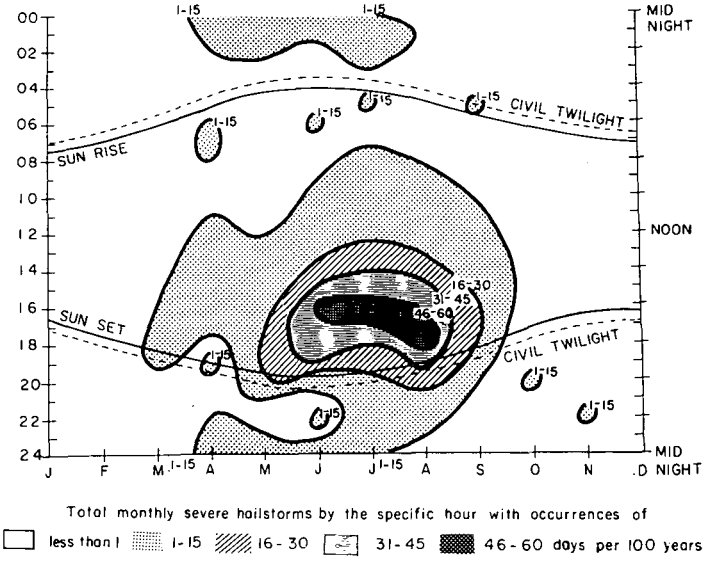

FIGURE 2.—Annual march of severe hailstorms in Wisconsin, 1924–62 (adjusted to 100-yr. period to facilitate comparison with figure 3.)

der may be heard at a distance of at least 10 mi., making it possible to hear thunderstorms over an area of more than 300 mi.[2] In contrast, hail is to be reported only when it occurs at or near the observing station, a much more limiting criterion. Given the spacing of the observing stations, and the much greater duration of thunderstorms in comparison to hailstorms, we are justified in assuming that most thunderstorms are reported, while many, or possibly most, hailstorms escape official detection.

The illustrations and tables cover varying periods of time. This is because the length of time of the official records is different for each station, and the authors chose to use the full length of available records to render a more complete presentation. In order that direct comparisons can be more easily made, data used in figures 2 and 3 have been adjusted to a 100-yr. period.

3. RESULTS

Figure 1 is the analysis of hailstorm distribution over Wisconsin for the period 1948 to 1957; punched cards were available for machine summarization for this period. Minor adjustments and smoothing were made in analyzing the cooperative data, but the chart closely approximates observed values. No station averaged more than 3.4 hailstorms per year for the period used.

The areas of greatest frequency of hailstorms are centered in Juneau County and in a small portion of the southwestern part of the State. Juneau County is in the Central Plain which is largely a region of sandy soil. Hills in the southwest lift air masses as they approach from the south and southwest.

The area of higher intensity of hail in the west-central portion of the State is a region of sandy loam soils and higher elevations.

The area of least hail frequency is in the northeastern portion of the State. Upwelling cold water in Lake Michigan and associated lake breezes tend to damp convective activity. The general flow of air across Wisconsin is from west to east, producing a moderate katabatic effect in the northeastern part of the State as the flow is from the Northern Upland, with elevations of 1400 to 1600 ft., to elevations of less than 800 ft. in the Door Peninsula area and the northern part of the Green Bay Fox River Lowland.

Figure 2 depicts the annual march of severe hailstorms in Wisconsin. The time of day when hail damage is small are seldom entered on the cooperative observational form or mentioned in news articles, thus limiting this part of the study to severe hailstorms.

The time of greatest severe hail intensity is between 1400 and 1900 CST from mid-May to mid-August. During this period, Wisconsin experiences high temperatures and maritime tropical air masses, thus providing maximum instability of air over the State. Practically no severe hailstorms occur from 0200 to 0900 CST or from September 15 to March 1.

Changnon [7], in analyzing the 25 most severe summer hailstorms in Illinois for the period 1915 to 1959, reported

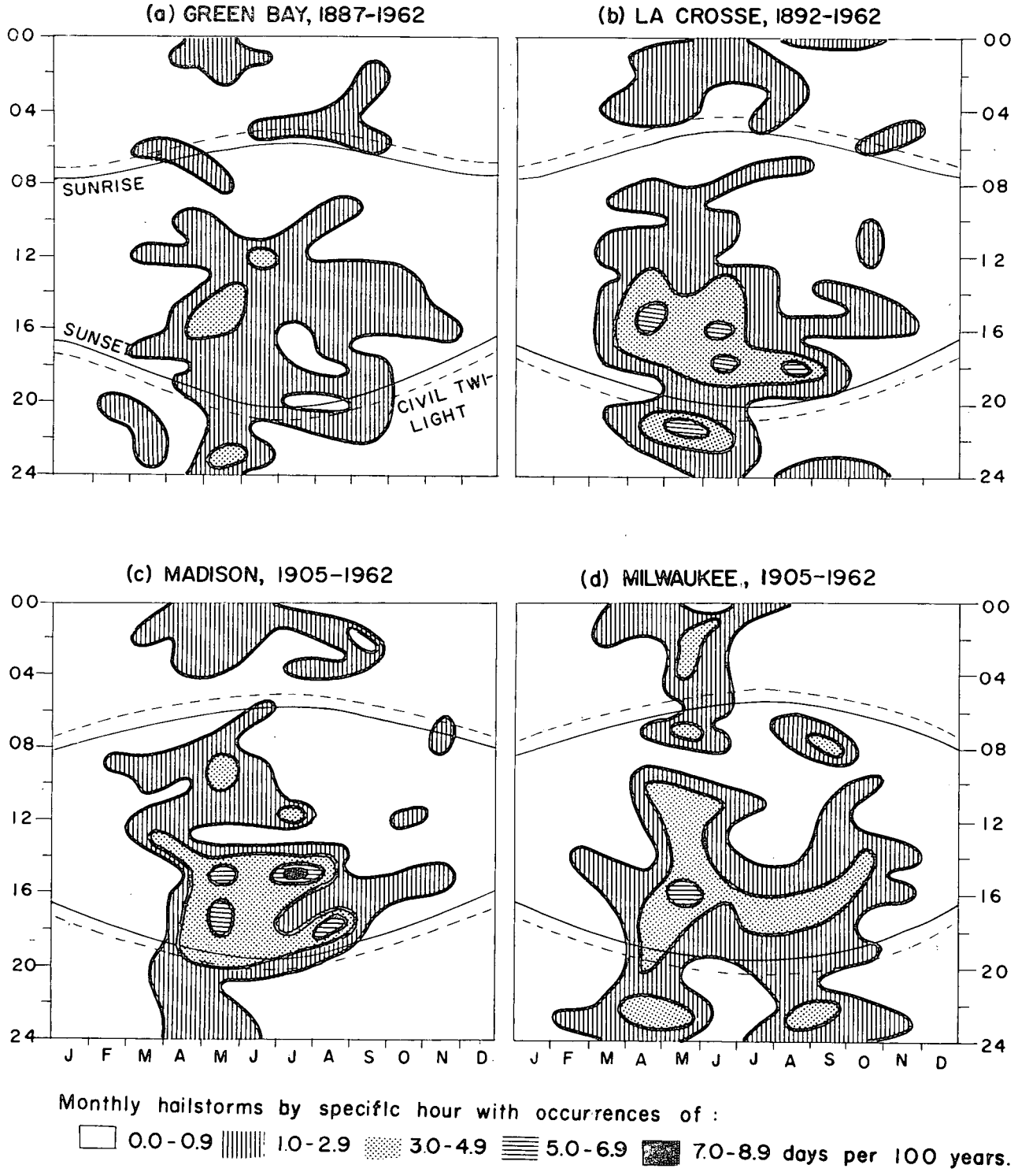

FIGURE 3.—Annual march of all hailstorms at four stations in Wisconsin. Data for the periods indicated have been adjusted to 100-yr. period for ease of comparison.

the most preferred 4-hr. period for hail was 1500 to 1900 CST for all synoptic types. In Wisconsin relatively few hailstorms occur between sunset and sunrise, correlating severe hail with maximum convective heating in Wisconsin as in Illinois.

The most probable time for a severe hailstorm in Wisconsin is approximately 1600 to 1800 CST in mid-July. As will be explained later in this report, the most frequent occurrence of all hailstorms is considerably different.

Figure 3 shows the annual and diurnal courses of all hailstorms for Wisconsin first-order weather stations. Data have been adjusted to 100 yr. in order that direct

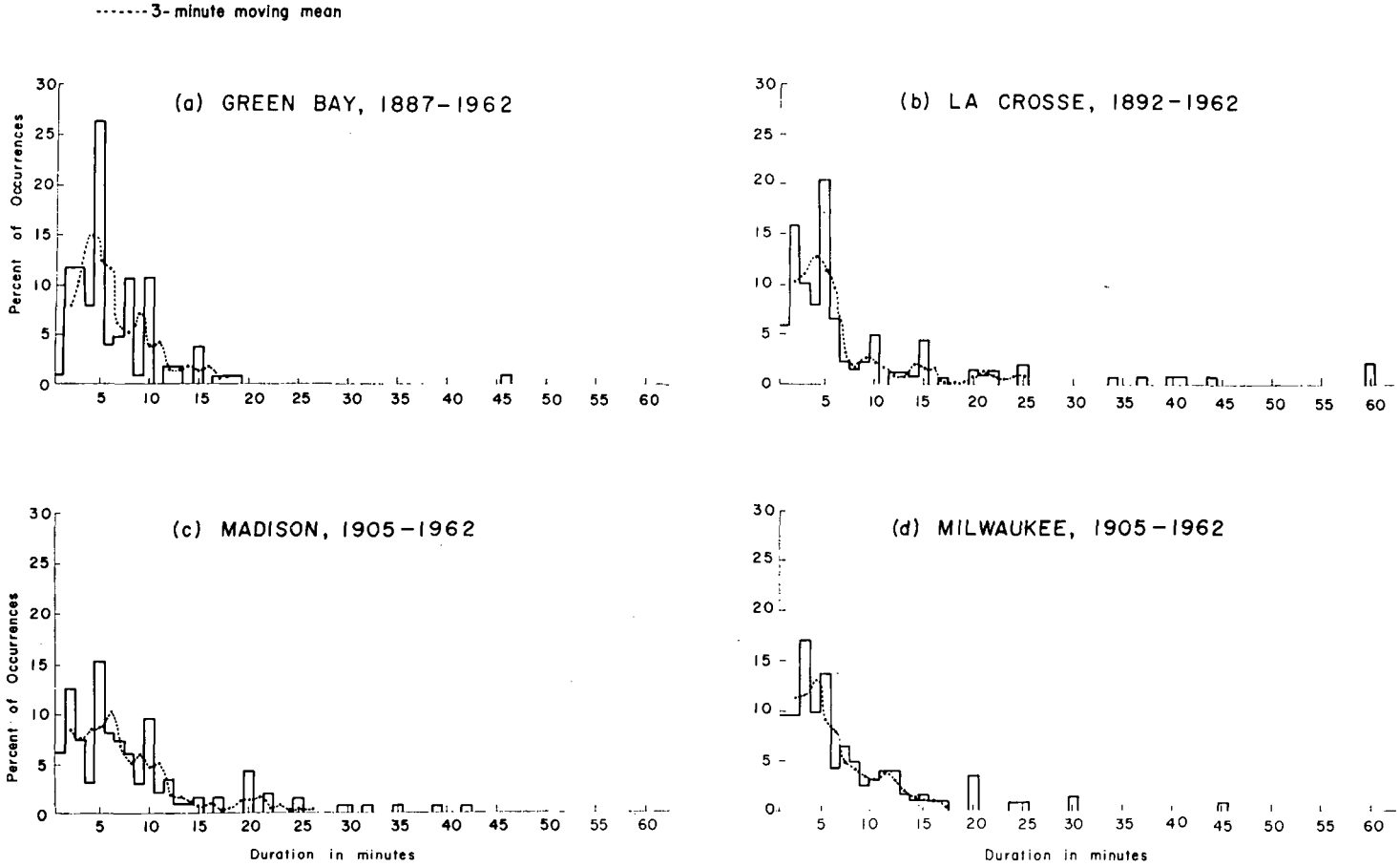

FIGURE 4.—Duration of hailstorms at the four stations.

comparisons can be made. Table 1 contains an actual count of all hailstorms for the period of record. All four stations have the greatest number of hailfalls between 1000 CST and sunset and between March 1 and August 1, with a slight accent on more hailstorms later in the season at Green Bay and Milwaukee. Significant is the infrequent occurrence of hail between sunset and 1400 CST the following day, after July 1. There is, of course, a remote chance of a hailstorm any place in the unshaded portion of the graph.

The graphs show that the bulk of hailfalls begin about a month later in the spring at Green Bay and Milwaukee than at the other two stations. A narrow strip of land along the shore of Lake Michigan is cooled by prevailing northeast winds during early and mid-spring. However in spite of this, the mean time of maximum occurrence of hail at each of the four stations is not far from 1600 CST on May 1.

As stated earlier in this paper, the mean time of occurrence of a severe hailstorm in Wisconsin is 1600–1800 CST in mid-July; this is the approximate time of day for maximum convective activity in Wisconsin and time of year for predominantly maritime tropical air from the Gulf of Mexico. It should be pointed out that many of the early-season hailstorms are not rated severe because the hail is of small size.

Figure 4 illustrates by histograms the duration of hailstorms in 1-min. intervals and by dotted lines the 3-min. moving trends. Inspection of the data shows that the

TABLE 1.—*Number of hailstorms for period of record by hour and month at four locations*

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
(a) GREEN BAY, 1887–1962													
01				1	1	2							4
02					2				1		1		4
03			1						1				2
04								1					1
05						1	1	1					3
06									1				1
07			1	1									2
08				1	1							1	3
09								1					1
10				1		1		2					4
11					2		1			1			4
12			1	2	1	4							8
13							1	1	1	1			4
14					3		2		1	1			7
15				1		1	1	1		1			5
16				3	3	2		2	1	1	1		13
17			1	1	1	1		1					5
18					1	2			2				5
19				1		2	1	1	1				6
20		1			1	3			1				6
21			1		1		1	1	1		1		6
22			2						1				3
23			1		3	1							5
24													0
Total	0	1	8	12	20	20	8	12	12	5	3	1	102

TABLE 1.—*Number of hailstorms for period of record by hour and month at four locations*—Continued

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
(b) LA CROSSE, 1892-1962													
01				2	2	1							5
02				1		1	1				1		4
03				2	1			1					4
04			1	2	1		1						5
05							1				1		2
06				1						1			2
07							1	2					3
08	1			1		1							3
09			1	1	1					1			4
10					1	1							2
11			1	2	2	1				1			7
12			2	1	1					1			5
13				2	1	3	1						7
14			1	3	1	2	1		1				9
15			1	4	3	2	1			1			12
16			3	4	3	5	2	2	1	1	1		22
17			2	2	2	1							7
18			1	3	2	5		4					15
19					1	2	2		1				6
20					1	1							2
21			1	2	4		1						8
22				3									3
23					1	2							3
24	1		1			1		1	2	1			7
Total	2	0	15	36	28	29	12	10	5	7	3	0	147
(c) MADISON, 1905-62													
01				1	1	1	1						4
02			1	1	1	1		1	2				7
03			1	2	1				1	1			6
04					1	1	1	1					4
05					1								1
06													0
07					1				1				2
08				1							1		2
09		1		1	2	1							5
10			1		2	1				1			5
11			1	1	1	1							4
12			2	3		1	2		1	2			11
13			1	1			1						3
14			4	1	1	1	2	3			1		13
15			2	2	3		5						12
16				2	2	1	2	1	1	1	1		11
17				2	5	1		3	1				12
18				2	4	2		2					10
19			1	1	1	1	1				1		6
20			1	1	2	3	1	1					9
21			1	1									2
22				1	1						1		3
23				1	2								3
24			1		1								2
Total	0	1	17	25	33	16	16	12	7	5	5	0	137
(d) MILWAUKEE, 1905-62													
01			1	1	1	3	1						7
02			1		2	1							4
03						1		1					2
04			1		2	1							4
05					1	1							2
06						1							1
07				1	2			1					4
08						1			2				3
09													0
10				2						1			3
11		1		1	3	2	1		1				9
12				1		1			1				3
13				1	2	1			1	1			6
14		1			3			1		2	1		8
15			1	1	2	2			1				7
16			1	1	4	2	1	2	2	1	1		15
17				2	2	1	2	2	2				11
18				2	2	1	3		1				9
19				3	1	1	1		1	1			8
20				2			1	1	1				5
21								1					1
22			2	2	1				2				7
23		1	1	2	3			3	1	1	1		13
24				1			1						2
Total	0	3	8	23	31	20	11	12	16	7	3	0	134

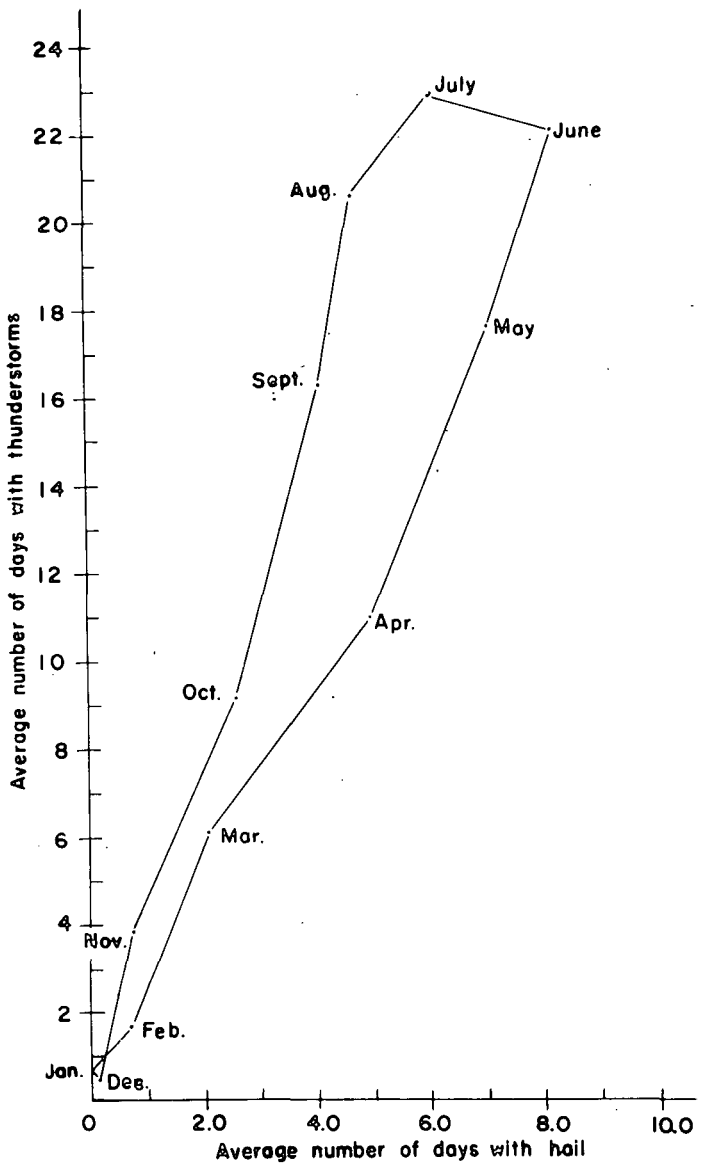

FIGURE 5.—Monthly relationship between days with hail and days with thunderstorms over the State of Wisconsin. (1914–57)

recorded duration of hailstorms is probably biased to the nearest 5 min.

In Green Bay, Madison, and La Crosse the most frequent duration interval for hailfalls is approximately 5 min., while at Milwaukee the most frequent duration time is 3 min. The graphs indicate that "hail shafts" or hail areas in a thunderstorm are localized and generally pass over a specific location in a few minutes with the forward motion of the thunderstorm. The few longer durations at La Crosse are due to the slight tendency of thunderstorms to become stationary in this part of the Mississippi Valley.

Schleusener and Handerson [14] found the average duration of hailfalls in the States of New York and Colorado to be 4.6 min.

Figure 5 shows the monthly relationship between days

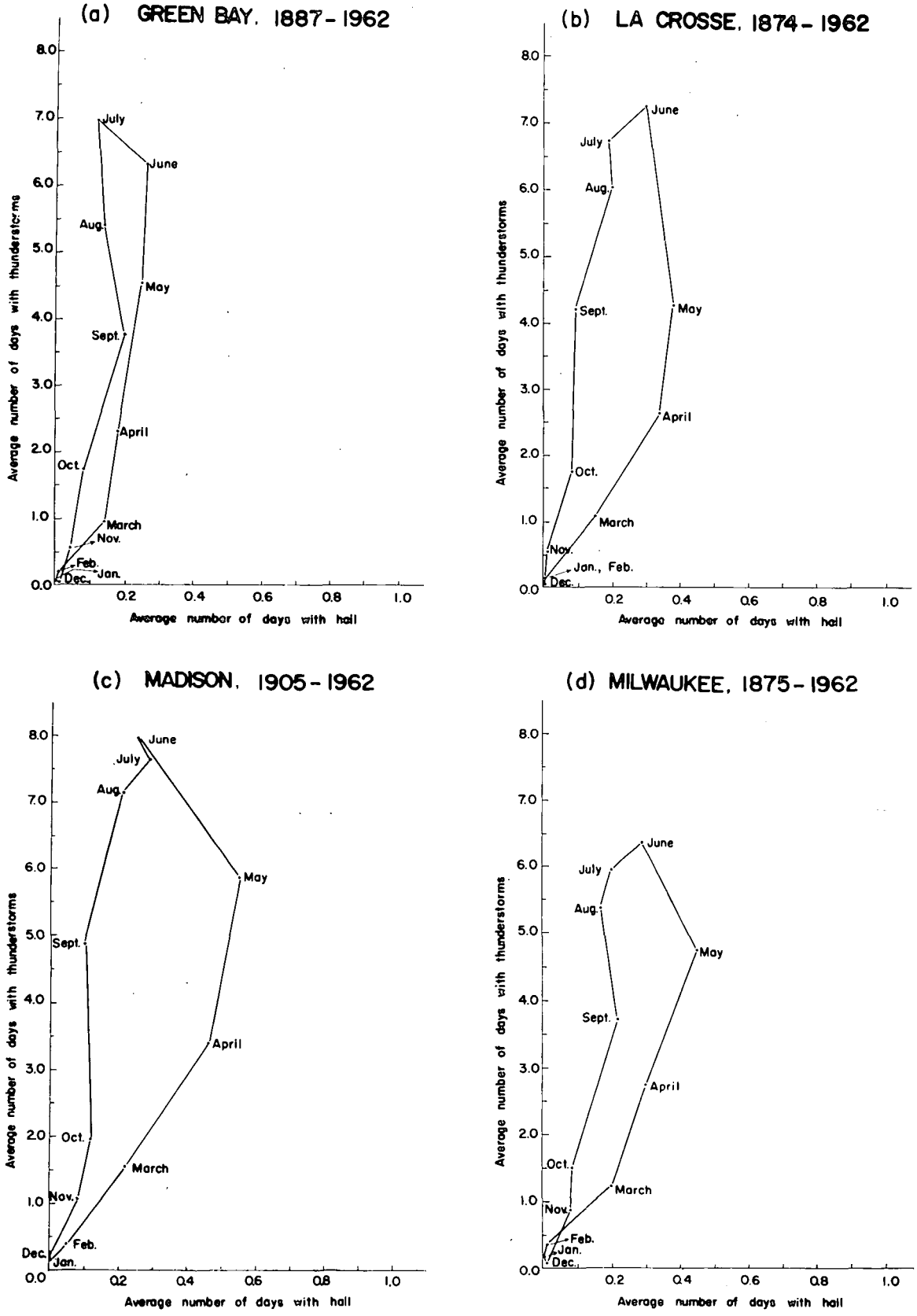

FIGURE 6.—Monthly relationship between days with hail and days with thunderstorms at the four weather stations in Wisconsin.

with hail and days with thunderstorms over Wisconsin. The ratio of hail to thunderstorms is higher for the cooler months from October through May. Most of the hailfalls during this period are of little consequence as the hail is small in size, usually less than ¼ in. in diameter.

The graph shows that for the entire State July is the month with the greatest number of thunderstorm days, while the largest numbers of hailstorm days occur in May and June. In July the ratio of hail days to thunderstorm days is approximately 1 to 4, while in April the ratio is 1 to 2. During the summer months of June, July, and August, thunderstorms have occurred on 2 out of 3 days and hail has fallen on about 1 out of 5 days. Days with hail and thunderstorms in the State are much more frequent than point studies would lead us to believe.

Figure 6 shows the monthly relationship between days with hail and days with thunderstorms at the four Weather Bureau stations. The greatest number of hailstorms occurs in May at all the stations except Green Bay, where June has the greatest number with May a close second. Madison has the greatest number of thunderstorms and likewise the greatest number of hailstorms. No attempt will be made to compare and contrast in detail the graphs of the four stations on a month-to-month basis; the general relationship is very interesting, not only on a month-to-month basis but also station-to-station. The ratio of hail days to thunderstorm days is highest in early spring and late autumn, at which times the number of occurrences of each is lower.

4. CONCLUSION

This analysis of hailstorms in Wisconsin discloses that the number of hailstorms decreases, in general, from the southwest to the northeast across the State. Severe hailstorms are most likely to occur between 1400 and 1900 CST from mid-May to mid-August in the State. All four first-order weather stations have the greatest number of hailfalls between 1000 CST and sunset and between March 1 and August 1, with more hailstorms later in the season at Green Bay and Milwaukee. After July 1, very few hailfalls occur between sunset and 1400 CST the following day.

The most frequent recorded duration of hailstorms was 5 min. at the four stations except Milwaukee, where the most frequent duration was only 3 min.

For the State average (1914–57), July has the greatest number of thunderstorm days, while June has the largest number of hailstorm days. Of course there are geographic differences; e.g., at Green Bay, June is the month with the greatest number of hailstorm days with May a close second, while at Madison April, May, and July each has more hail days than June. The ratio of hail days to thunderstorm days is highest in early spring and late autumn.

As has been mentioned before, the completeness of statewide observations of hail is far less than that for thunderstorms, but the four first-order weather stations provide a fairly complete and accurate estimate of the hail-thunderstorm day ratio.

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